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ON THE WORK OF CHINESE PLANT PHYSIOLOGISTS

/Following is the translation of an article by Lo Tsung-lo (translated into Russian from the Chinese by Chao Shih-hsu), Director of Plant Physiology of the Academy of Sciences, Chinese People's Republic, entitled O Rabote Kitaiskikh Fiziologov Rastenii (English version above) in Fiziologiya Rasteniy (Plant Physiology), Vol. VII, No. 2, pages 247-255, Moscow, 1960./

The study of plant physiology began in China in 1917, but the organization of research facilities and training bases as well as the development of scientific research and the training of scientific workers began only in 1930. From this year on until the liberation of the country the main centers of research studies in plant physiology were located in a few universities and the work was carried on with inadequate resources and equipment. Appropriate calculations showed that for the 30 years before liberation no more than 160 studies in plant physiology were published, the majority of which had been made abroad. The published works were confined to problems of growth physiology, mineral nutrition and metabolism; only a few people concerned themselves with such important areas of plant physiology as photosynthesis and the physiology of plants under water conditions. There were very few research institutions for this branch of science. No more than 20 specialists in plant physiology were trained during these 30 years.

After liberation, under the leadership and with the aid of the Party and the government, the study of plant physiology assumed a new character. A laboratory for plant physiology was established in the Academy of Sciences in 1950 and soon after that (in the spring of 1953) the laboratory was reorganized into the Institute of Plant Physiology. In 1956 the Peiping Laboratory of Plant Physiology was established. At present there are no special divisions of plant physiology in three universities, and chairs in plant physiology were organized in more than 50 Higher Institutes of Learning. Plant physiology departments also

were established in agricultural research institutions. At present the number of workers in only two of the institutions of the Academy of Sciences system already exceeds 300, and if the plant physiology workers in the Higher Institutes of Learning and of the Research Institutes in agriculture were also counted, then the total number of physiologists would be more than 500. But even with this rapid expansion the development of plant physiology does not meet the demands of the state. For the past ten years much attention has been given to establishing and equipping new institutions and providing for the training of workers' cadres. At the same time, research work has been carried on intensively; as a result about 300 studies have been published, which is about twice the number of studies published in the 30 years before liberation. This in itself speaks eloquently for the advantages of the socialistic system.

Of great importance is the fact that the Party and the government pointed out the direction the scientific studies should take. Before liberation scientists elected to study subjects having no relation to the needs of the state; they even thought that the further removed from reality were the selected subjects, the higher was the level of work. Consequently the studies were carried on without an overall plan. However, the Party and the government pointed out that science must serve the development of the people's economy -- that theory must be closely related to practice. We have consistently tried to follow this road for the past ten years. In spite of the rudimentary nature of the work, we have gone into various sections of the country to study the problems which faced us in practice, ready to do our utmost to seek their solution. We selected for study rice, wheat, cotton and actinomycetes fungi and, in working out the themes of research for the various institutions we chose, as much as possible, problems closely related to agricultural practice. For the past 10 years the research studies in plant physiology have been devoted primarily to the physiology of rice.

The great advances made in agriculture in our country in 1958 greatly stimulated the studies of the physiology of plants. In order to deduce generalizations from the advanced experience of the peasants in obtaining large crops, the majority of scientific workers went into the people's communes, where the production fields served as experimental plots. The studies were carried on with the aid of the peasants. The methods of work were changed. We, the physiologists, learning from the rich experience of the peasants and becoming acquainted with the basic steps in agricultural production, developed the problems posed for plant physiology and thus accomplished our task in accord-

ance with the slogan "science in the service of production." Simultaneously the foundation for the development of plant physiology was laid and the level of study was raised. In turn, the scientific workers spread scientific knowledge and research methods among the peasants. One can forsee from the peasants' attitude to production that in the near future scientific research work in plant physiology will be widely developed in the communes. Thus, knowledge of plant physiology will rapidly be disseminated among the people in accordance with the party's call "science for the people," and the number and quality of workers in this field will increase, thus aiding the development of plant physiology in China.

All branches of plant physiology must be developed in order to obtain solutions to complex practical problems. Therefore much attention was paid to the development of branches of our science which had lagged behind, such as photosynthesis, physiology of plants under water, stability, growth and development, etc. At present, in addition to studies on the physiology of the cell, studies are already being carried on in all the leading branches of plant physiology.

Science in a socialist country must serve the general economic well being, and therefore it must be developed according to a plan. "The Plan of Development of the Principal Branches of Science and Technology in our Country," which was elaborated by our scientists in 1956, is a turning point in the history of the development of science in the Chinese People's Republic. The research studies of the past 10 years conform basically to the demands of this plan.

After liberation both the Party and the government repeatedly directed us to study seriously the progressive science of the Soviet Union. We became acquainted with the theories of I. V. Michurin and T. D. Lysenko; we followed the Soviet literature and, through exchanges of visits between physiologists of both countries, we learned of the status of plant physiology studies in the Soviet Union. We believe that one of the characteristic features of Soviet physiology is the fact that it pays considerable attention to I. V. Michurin's concept of the unity of the organism and its environment. By changing the environment one may change the hereditary properties of the living organism; thereby the possibility of controlling organisms in the interests of mankind is indicated. The second feature of the Soviet science is the integral concept, which emphasizes the inter dependence among the organs within the organism and the interdependence of the individual and his environment. The third characteristic feature of Soviet

plant physiology is the idea that the plant requires different environmental conditions at different stages of its development, and that it reacts differently to various conditions. We note with satisfaction that all three concepts have had a marked effect upon plant physiology studies in our country during the last 10 years, especially in the fields of the physiology of growth and development, the physiology of plants under water and the physiology of resistance.

I shall set forth below the results of studies in plant physiology in our country for the last 10 years. It is impossible in a short article to examine all the studies and to give an exhaustive description of them. Therefore I shall examine only a few of the most important studies.

The physiology of Growth in a Water Regime.

Rice is one of the principal grains cultivated in our country. Naturally, the investigators first of all paid attention to the physiology of rice grown under water. Rice grows under conditions of permanent flooding. This is taught by the millenium-old experience of the peasants in growing rice. The depth of the water and the total water required for rice are the most important problems in the rational irrigation of rice. Under natural conditions of the Tientsin region, the growth and productivity of rice increase as the water layer rises. When the soil is only moist the productivity of rice decreases, whereas the deeper the water the stronger and more rapidly the rice plant grows. (Ts'ui Tjihn and others, 1956). The water layer aids in the absorption of NH_4^+ and Fe^{++} by the rice plant, but decreases the contents of NO_3^-, Fe^{+++} and NaCl in the plant. The deep water also acts to regulate the temperature: the amplitude of the temperature fluctuation in 24 hours is less in the deeper layer (Ts'ui Tjihn and others, unpublished).

Although the rice plants are hydrophillic, when the water is too deep unfavorable conditions affecting their growth are created; the accumulation of large quantities of water in plots where rice is planted is one of the causes of destruction and decay of the plantings (Ts'ui Tjihn, 1955; Chou Ch'ang-hsin, 1957' Hu Huo-shihn, 1957). When deep flooding occurs the height of the plants increases, their dry weight decreases, and the respiration intensity is depressed in various degrees. The younger the plant, the more its vegetative portion is damaged. If the flooding occurs in the phase of spike differentiation, the fruit-bearing organs are greatly damaged: either abnormal spikes appear or the spikes are destroyed. The damage due to flooding occurs more in the phase of spike differentiation than in the phases of budding and blossoming (Wang Hung-ch'ung,

Lo Tsung-10, 1956). Experiments in aeration, shading and regulation of the water temperature have shown that the cause of the destruction of rice plants under conditions of inundation, is the oxygen shortage in the water which leads to metabolic disturbances. When the water temperature is low but there is additional exposure to light and artificial aeration, the shortage of oxygen is less. However, as a result of the fact that the synthetic process is unable to compensate for the losses in the plants, they are lost for lack of nourishment. But when the water temperature is high and the field is shaded, the oxygen shortage is greater, causing alcohol and other poisonous substances to accumulate in the plants. In spite of the presence in the plants also of residues of sugar and nitrogenous substances, the plants die rapidly (Wang Hung-ch'ung and others, unpublished). In cultivating the plain rice of the Lao-lai-ch'ing variety as well as the nang-t'ang-hang dicot variety without irrigation, the fertility is less than that under constant flooding. But the decrease in the dicot crop is less than that in the Lao-lai-ch'ing crop. Under similar conditions of soil moistness (45% of total moisture capacity) the content of water in plants of the Nang-t'ang-hang variety is greater than that in plants of the Lao-lai-ch'ing variety. Correspondingly, in plants of the Nang-t'ang-hang variety the moisture deficiency is amller, the quantity of free water is greater, the ratio of free water to combined water is higher, the loss of electrolytes by osmosis is smaller, the heat resistance of the tissues is stronger and, finally, the root system is more developed, as compared with the Lao-lai-ch'ing variety. All this shows that the resistance to drought is superior in the dicot rice as compared with the common rice, when both are inundated during growth.

In the culture of Chinese cabbage under various conditions of water supply the highest rate of photosynthesis was observed at a soil moistness of 70%, and the ascorbinoxidase activity is greatest under conditions of low soil humidity. When the water supply is unfavorable, the amount of reduced ascorbinoxidase decreases and the amount of the oxidizing form increases. (Wang Hung-ch'ung and others, unpublished).

Mineral Nutrition. One may influence the growth and development of agricultural plants by maintaining various levels of mineral nutrition at various phases of development. The nutrition of wheat in the tiller phase determines the bushiness and the number of spikes (T'ang Yu-wyi and others, 1955; Pao Wing-k'uei and Yian Yu-jui, 1954). Plentiful mineral feeding of wheat and rice in the period from

the tube phase to the ear phase aids in the differentiation of the flower organs, raises the productive bushiness, increases the binding of the seeds on the spike, and as a result a greater yield is obtained (T'ang Yu-wyi and others, 1955; Lei Huong-shu and others, 1956; Pao-Wing-k'uei and Yian Yu-jui, 1954, 1956, 1957). An increase in the level of mineral feeding after the spike phase increases the contents of albumin in the seeds, but prolongs the maturation period (T'ang Yu-wyi and others, 1955). If the nitrogen, phosphorus and potassium feeding are intensified in the tube phase, the increase of nitrogen and phosphorus in the leaves, vaginal sheaths and spikes of the principal stems of the wheat plants is greater than when mineral feeding is intensified in other phases of development (Ni-Ching-shang and others, 1956). One part of the latter study was carried out on irrigated cultures, another part was made in vegetation vessels and another part was conducted in field experiments. The results in all cases were similar.

The rapidity of ion absorption by the plants depended upon the conditions under which the plants were cultivated. Rice sprouts grown in distilled water absorbed nitrogen more rapidly in the ammoniacal form (NH_4--N) than in other forms. However, sprouts in a nutrient solution behaved quite differently. The presence of the ion K^+ aided the absorption of NO_3 by wheat sprouts, and at the same time the yield of reduced sugars also increased (Ni Chung-shang, unpublished). The addition of potassium salts to the soil increased the content of cations in the plants, but the content of calcium decreased (Yu T'ien-jin and others, 1956).

Trace Elements. Copper, manganese, zinc, molybdenum and other elements in low concentrations stimulate the respiration of rice sprouts. Sprouts treated with these elements are less sensitive to the action of respiration inhibitors such as potassium cyanide, iodoacetic acid and others, than are sprouts which have not been so treated (Chao Su-wuo, Ts'ui Tjihn, unpublished). Zinc aids the distribution of growth substances in tomato plants, in larger amounts to the young leaves of the upper layers and in smaller amounts to the old leaves of the lower layers (Ts'ui Tjihn, 1954). Zinc also participates in the synthesis of tryptophan, as is confirmed by the following experiments. Indole and serine were introduced by the vacuum infiltration method into normal tomato leaves and into leaves lacking in zinc. It was found that the leaves of normal plants contained a great deal of tryptophan, while leaves of plants deficient in zinc contained very little. The shortage of zinc greatly decreased the activity of peroxidase and polyphenoloxidase in plants. Two weeks after the addition of

zinc to the feeding solution the activity of these two enzymes was fully restored.

Trace quantities of many elements stimulate the growth of plants. For example, manganese, zinc and boron have a positive effect upon the leaf vaginal sheaths of wheat (Lu Ting-chi, Lo Tsung-lo, 1950); zinc, copper, manganese, iron, molybdenum, boron, selenium and lead acted upon wheat shoots (Ts'ui Tjihn, 1954); zinc, copper, manganese and boron act upon rice shoots (Li Ch'ong yu, Liu Wu-ling, 1956; Chao Su-wuou, Ts'ui Tjihn, unpublished).

If the seeds are treated with traces of elements before vernalization, the process of vernalization is accelerated (Ts'ui Tjihn, Wang Pao-k'uei, 1957).

Many studies were made, regarding the use of traces of elements in agriculture, especially in rice planting. Some researchers used them in treating the seeds (Miu Hsia-jang, 1956), and others used them to supplement the root feeding (Wang Hsiang-k'ung, 1956; Ts'ui Tjihn, Wang Pao-k'uei, unpublished). All these experiments, according to the communications of the authors, had the effect of increasing the rice yield. In addition, positive results were also obtained by using traces of some elements in the cultivation of wheat (Tai I-tian, 1955; Wang Hsiang-k'ung, and others, 1956) of soybeans (Chu Ch'ih, 1956; Wu Liui, Hsing Ch'ihng-yun, 1958; Wang Hsiang-k'ung, 1956) of the cotton plant (Wang Hsiang-k'ung and others, 1956) and of vegetables (Lia Hsia-sheng and others, 1955).

Photosynthesis. Green cells, may reduce organic substances having an aldehyde group, for example, acetic and benzoic aldehydes, thus freeing oxygen; chlorella may reduce furfurole (Yuan Lung-fei, T'ang Pyi-sung, 1951). The process of photoreduction in isolated chloroplasts at the beginning and at the end of their exposure to light has a clearly expressed induction period (Wang T'ien-tao, unpublished).

Isolated leaf blades fed with sugars form starch more rapidly when exposed to light than in darkness. By using various inhibitors and by varying the intensity of the illumination or the composition of the air, researchers established that light participates in the formation of phosphoric acid ethers. The process takes place in the presence of a small quantity of oxygen (Li Shu-hsiung, Ying Hung-chang, 1957).

The cellullar fluid in spinach contains carboanhydrase; this enzyme may be related to the fixation of CO_2 (Yuan Lung-fyi, T'ang Pyi-sung, 1951). Upon addition of fumaric acid and ammonia gas to the plant extract, the formation of glutamic acid may be observed; this shows that in addition to the reaction of ammonia the fixation of CO_2 also takes place

(T'ang Pyi-sung, Chou Pyi-chihng and others, 1957). Various products are formed in plants upon the assimilation of CO_2, depending on the conditions. By use of $C^{14}O_2$ it was found that different organic acids were formed in the chlorella under red and blue illuminations. The properties of the assimilation products depended also upon the phase of development. For instance, formation of cellulose tissue was observed during the ear phase, and during the milk maturity phase all the assimilation products were soluble in alcohol or were substances which hydrolyze in weak solution (Sheng Yun-kang, Sheng Kung-mao, unpublished).

The movement, transformation and distribution of photosynthesis products in cotton plants greatly influence the falling off of the pods. It was shown by means of shading ringing /cutting a ring in the stalk?/, introduction of sugars into the plants and analysis of the distribution of organic substances into various parts of the plants, that the principal cause of the falling off of the pods was the inadequate supply of nutrients. There were fewer pods on branches subjected to ringing, the more leaves they contained. If the ratio of the number of leaves to the number of blossoms was 2:1, then the feeding of the young pods was ensured; and even the unfertilized ovaries would not fall off (Ching Ch'eng-chung, 1954-1956). The yield of rice seed is largely determined by the photosynthesis processes following blossoming. In one experiment, removing the leaves proved that leaves were the principal organs of photosynthesis; the photosynthetic capacity of the stalk and spike was relatively small. When a part of the leaves was removed the yield did not decrease directly proportionally, which indicates the compensatory capacity of the remaining leaves (Ying Hung-chang, 1958, Chang Wang-shu 1958; Sung Jan-ch'ihn, 1957).

An experiment on rice with the use of $C^{14}O_2$ proved that a considerable quantity of assimilation products accumulate in the stalk before spike formation. Following blossoming and in the milky maturity phase, most of the assimilation products flow from the leaves into the spike of the stalk, the movement into other parts being insignificant. When one root system has two stalks, the assimilation products do not flow from one stalk to the other. However, when the spike is removed from one of the stalks, then the movement of assimilation products from the leaves of the stalk without the spike into the other stalk may be observed (Shen Kung-mao, Ying Hung-chang, 1958).

The rate of photosynthesis of each leaf depends upon its position on the stalk (Ching Ch'eng-chung and others, 1954) and also upon the solar radiation during the day (Ni Ching-shang, Shih Chio-nai, 1957; Tjung-hung-shu, 1954; Li

Shu-Hjiung, unpublished).

Experiments with rice in vegetation vessels and in the field showed that the leaf surface area was greatest in the spike phase, and the pure photosynthetic productivity was high in the tiller phase, decreasing gradually toward the spike phase, and then increasing again in the spike phase and the blossoming phase, reaching its maximum in the milk maturity phase (Ch'eng Ts'uang-lung, 1958; Hsia Shu-fang, unpublished).

Metabolism and Respiration. The synthesis of starch in rice plants during the period from blooming to maturity depends upon the phosphorylase activity. This activity is slight in the blooming phase and increases gradually, reaching its maximum in the milk and gum maturity phases. During the wax maturity phase it gradually decreases, and disappears almost completely at the moment of full maturity. Such changes in phosphorylase activity coincide with changes in the rapidity of accumulation of starch in the seed. B-amylase is the hydrolytic enzyme in rice seed; the variation of its activity is similar to that of phosphorylase but less extreme. Maltose is not found in ripened rice seeds. An experiment with radiocarbon (C^{14}) showed that as soon as maltose formed it was converted rapidly into sucrose. The respiration intensity reaches its maximum in the milk and gum maturity phases (Ying Hung-chang, 1956). The study of wheat and rice metabolism during seed formation and storage after harvesting showed that the maximum speed of accumulation and movement of substances occurred within the first one to three weeks after blooming. The oxygen expiration and the phosphorylase activity are also greatest during this period (Ying Hung-chang, 1956; Chao T'ung-fang, unpublished). Ascorbinoxidase activity in the wheat seed reaches its maximum in the period of the first one to two weeks following blooming. Polyphenoloxidase is not evident at this time; however, it is observed from the fourth week on. Citochromoxidase activity is greatest during the process of conservation following harvesting (Chao T'ung-fang, 1958).

The respiration intensity of cotton increases greatly during its blooming. The respiration intensity in normally developing pods was found to be consistently greater than in pods that tended to fall off. In pods that did not fall off the content of soluble sugar was greater two days after blooming, while in pods that fell off this phenomenon was not observed. Thus the main reason the pods fell off was disclosed as an inadequate sugar supply as a result of which growth stops and respiration decreases (Ching Ch'eng-chung, 1956).

The respiration intensity and catalase activity of

the fertilized flower of the orchid are greater than those of an unfertilized flower. Starch in a fertilized ovary develops more slowly than starch in an unfertilized ovary (Ts'ao Zung-sung, 1952).

Enzyme activity of the glycose system E-M-P (Embden-Meyerhof-Parnas) is present during the respiration of rice shoots, as is the krebs tricarbonic acid (T'ang P'ui-sung and others, 1955) and a pentose process (Tai Yung-ling, Ch'iu Lo-ch'ang, unpublished). The activity of cytochromoxidase, ascorbinoxidase is also observed and polyphenoloxidase in the terminal oxidase system.

Rice shoots are capable of oxidizing butyric acid, some amino acids, and acetic, fumaric, succinic and other acids. Therefore T'ang P'i-sung considers that rice metabolism comprises "a polycyclical path." The process takes place in various ways under aerobic and anaerobic conditions.

When rice shoots are cultivated on a substratum containing NO_3, they develop a nitrate reductase. The emergence of this ensyme requires, at best, an induction period of two to five hours. When NO_3 is removed from the substratum the enzyme disappears within two days, which shows the capacity of the substratum to induce the formation of an adaptive enzyme (T'ang Pyi-sung, Wu Hsiang-yü, 1957, 1958).

Growth and Development

A great number of studies have been made during the last 10 years on rice, wheat and cotton. In these studies hundreds of varieties of cultivated plants were used and the experiments were conducted on a scale involving the entire country. The following are the basic results of the studies on the growth and development of the plants:

The vernalization temperature of rice is between 15° to 30°, and the length of the vernalization stage is not more than 12 days (T'ang Hsi-hua and others, 1955). The latitude, elevation above sea level, and the times of planting and ripening are important factors which affect the reaction of rice to light (Wu Kung-nang, 1957). The differentiation in the growth cone of the rice stalk may begin only after the completion of the light /coleoptile?/ stage. A definite combination of feeding and temperature is required for the passing of the light stage when the days are short (T'ang Hsi-hua and others, 1955, 1956).

The K'ai-yung perennial cotton plant with nonjoined cotyledons requires a short day for the normal light stage (Hsiu Yuang-lin, unpublished).

The varieties of winter wheat cultivated in this country were also studied (Huang Hsi-fang, Li Hsieh-shu and

others, 1956; Ts'ui Hsi-ling and others, 1955).

The light phase in wheat begins before the differentiation of the growth cone and ends during the formation of the pistils and stamens (Huang Hung-shu and others, 1957; Hsia Tjing-ou, 1955; Ch'ii Hsi-ling, 1955). During vernalization the amount of nucleic acid in the wheat germ increases (Li Shu-hsung and Ying Hung-chang, 1956).

The vernalization of garlic may take place concurrently with the germination of the stalk. The development of the stalk (stem) requires low temperature, and a long day is necessary for the formation of the bulb (Li Shu-hsuang and others, 1954).

The vernalization stage of rape normally requires a temperature between zero and two degrees, and usually takes 18 to 20 days. Lengthening the vernalization period speeds the later budding and blossoming. Fourteen hours of illumination per day is adequate for the normal growth and development of rape. The effects of lengthening the vernalization period and shortening the time of illumination per day are similar to the effects of lengthening the daily illumination period and shortening the vernalization. In experiments with nonvernalized shoots of rape grafted on blossoming stalks and then placed in a hothouse at a temperature above 20 degrees -- that is, a temperature unfavorable for vernalization -- the grafts developed buds which blossomed into flowers (Ni Ching-nang and others, 1955).

Numerous studies have been made analyzing the phases of such cultivated plants as cabbage (Li Shu-hsuan and others, 1957), soybeans (Wang Ching-ling and others, 1956), hemp (Hsiao P'u and others, 1951), ramie (Li Ching-tao and others, 1955 and 1957; T'ang Hsi-hua and others, 1958), flax and jute (Yü Tjih-ch'eng and others, 1956 and 1958).

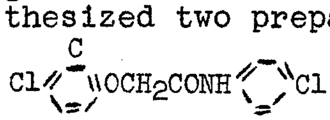
For vernalized plants, the blossoming and maturing are accelerated and the crops are increased (T'ang Yu-wyi, 1951; Huang Hsi-k'ang, 1950; Chang Pang-hsieh, 1955; Ts'ai Ch'ih-yuung, 1955; Chang Li-tao, 1953 and 1955; Tai Wang-huang, 1955; Hsu Hsing, 1957).

Growth curves of many cultivated plants were studied; For example, sesame (Tjan Ing-Hsiaong, 1951) Ingolfera decora L. Yang Yung-k'uei and others, 1951), hemp (Hu Min-hsiang, 1950; Hsu Nai-chang, 1953; Ch'eng Hsi-ch'eng and others, 1954), and cotton (Kuo Hsing-hsiang and others, 1952). Observations were carried out on the influence of the temperature and environmental conditions upon the growth and development of plants or their organs (Ch'eng Hsi-ch'en and others, 1955, 1957; Yang K'ai-ch'yu, 1958; Wang Li-ch'yuong and others, 1956; Lin Shih-ch'en and others, 1956). Experiments were carried out to determine the effect of environmental

factors on sex transformation (Ch'ieho Tsung-sung, 1957; Io Io-hua, 1954; Hsu Ting-chiung, 1958). The length of the rest period of the seeds is not the same in all varieties of wheat; seeds at rest react differently to high temperatures when they are disturbed. In subspecies of Indian rice there is no rest period, in contrast to Japanese and Chinese subspecies (Chao Shung-fang and others, 1956-1959).

In raising isolated tissues in an artificial environment it was found that the amounts of some substances are sometimes greater in these tissues than in the mother tissues. For example, there is more citric acid in an isolated tomato root than in the root of the mother plant (Chou Hsia-hue, 1958). The calluses of carrots, tobacco and sunflowers after being raised in an artificial environment have terminal oxidase systems differing from those of the mother tissues (Lo Shi-wyi and Li Shao-hua, 1957).

Growth Stimulators. The chemical division of Nanking University (Yang Shih-hsiang, 1957) synthesized more than 100 growth stimulators between 1956 and 1959. Ch'eng Lu-yü synthesized two preparations which are derivatives of 2,4-D:



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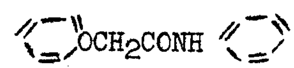

They are used as 2% solutions, and their effectiveness upon dicotyledonous plants is greater than that of 2,4-D.

A weak solution of 2,4-D stimulated the respiration of the plant, while a strong solution inhibited it. The effect of 2,4-D on the absorption of O_2 was greater than the effect on the liberation of CO_2, as a result of which the respiration coefficient increased (Lou Ch'eng-hou and others).

Gibberellin stimulates the respiration of yeast, Phodotorula, and germinated seeds. Growth substances influence the viscosity of the protoplasm (Ku Kung-wyi, 1957). Growth substances travel in the willow stalk through the phloem downwards, but not by simple diffusion -- live cells play an important role. The polarized movement of growth substances is not affected by gravity, and horizontal translocation is of great importance, as was proven by changing the direction of ringing (Lo Tsung-lo, and T'ang Yu-wyi, 1957).

The oxidase auxin, liberated from ethyolized pea shoots, is capable of destroying the growth substances in oat coleopties; since this oxidase is a strictly specialized 3-indoleacetic acid, the growth substance in the oat coleoptiles is a 3-indoleacetic acid, and not auxin a or auxin b (T'ang Yu-Wyi, unpublished).

In comparing the effect of the 3-indoleacetic acid

upon the growth of wheat coleoptiles with the effect of elements in trace amounts (Mn, Zn, B) it was found that the 3-indoleacetic acid was less stimulating to growth than were these elements (Lu Ting-chih, Lo Tsung-lo, 1950). Some scientists think that the stimulatory action of the trace elements is closely related to growth substances. For example, if the amount of Zn in tomato plants is great, then the amount of growth substances present is also large (Ts'ui Tjihn, 1954).

Many a study was devoted to the use of auxin and heteroauxin in production; for example, 2,4-D (Lou Ch'eng-hou, Suie Ing-lung and others, 1951 and 1957) and 2,4,5-T (The Administration of Agriculture of Yiang-ch'ing County in Heilung Kiang Province, 1958) were tested as herbicides for weeds over large areas. 2,4-D was also used against the defoliation of tomato buds and of other cultivated plants and against germs (Hsuie Ying-lung and others, 1951; Li Shu-suong and others, 1954-1956; Mi Suo-yu, 1956) and also against the defoliation of the leaves of Chinese cabbage in storage (Li Shu-suang, 1952; Lou Ch'eng-hou and others, 1954). All these studies gave positive results.

The treatment of potatoes with the preparation MH for three to four weeks before harvest, or the treatment with the preparation NAA (naphthylacetic acid) after harvest, may inhibit the growth of the tubers in storage (Li Shu-suang, Suyeh Ying-lun and others, 1957; Chao T'ung Fang). The use of NAA, 2,4-D and other substances in the treatment of grafts aids in the development of the root systems of the Brazilian rubber tree (Hevea brasiliansis) (Lo Shih Wyi and others, 1952), /and of/ Zelkova Schneideriana (P'ang Ch'en-huong, 1956-1958), and increases their viability. According to some authors, one may control the flowering and fruiting of pineapple with the use of growth substances (Huang Chang-hsiong and others, 1956). Following the treatment of Cyclamen indicum with 2,4-D, the size of the tubers and the number of flowers increases and blossoming was accelerated (Lou Ch'eng-hou and others, 1955). The treatment of soybeans with the TIBA preparation accelerates development and raises the number of buds (Yiang Hsiu-Ch'ing and others, 1956). Experiments are being conducted on a large scale on the use of gibberelline in the field and in fruit and vegetable production.

Irritability and Correlations. Data were obtained by determining the electrical impedance and the polarity effect in live tissues which led to the conclusion that while the plant cell is an electrical conductor, (since it is rich in electrolytes), it is surrounded by a protoplasmic coating which acts almost like an insulator. The thinness of the plasmoderm separating the cells greatly weakens the electrical

resistance between the cells and thus provides an effective path for ions of mineral substances and electrons (Lou Ch'eng-hou, 1955). It has been observed that during the formation of pollen cells of garlic, wheat and other cultivated plants, the protoplasm moves easily through the plasmoderm of young, newly formed tissues (Wu Su-suang, 1955; Tjihng Kuo-ch'ang, 1956). The movement of the protoplasm among the cells may be observed in mature tissues. In growing and old tissues of garlic the cell structure is partially reorganized, the protoplasm moving from one cell into another (Long Ch'eng-hou and others, 1956). Such a movement of protoplasm through the cell membranes is regarded as one form of the transportation of substances. The respiration inhibitors suppress this movement. This shows that the energy of respiration is used to maintain the movement (Yuang Lung-fyi, unpublished).

The responsiveness of the mimosa plant (Mimosa pudica) to electrical stimulation varies over a 24-hour period. It is most sensitive in the evening, and does not react to stimulation at dawn (Suieh Ing-lung, 1955). The principal stems of cultivated squash plants react markedly to stimulation, although no movement of the external parts of the plant is evident, and the area over which the electrical movement is distributed is very wide. Such a transmission takes place through the vascular fascicles (Lou Ch'eng-hou, 1958). Stimulation by burns causes the transmission of a negative electric potential. This transmission is very rapid and cannot be explained as the diffusion of damaged substances.

Stability. The stability of agricultural plants depends upon the stage of development and phase of growth. Rice of the Lao-lai-ch'ing variety in the tiller and tube phases is scarcely damaged by drought, and subsequent showers even stimulate growth slightly. But before earing this variety of rice is very much affected by drought, with the result that the ear and flower scales as well as the blossoms do not develop fully. If the other variety of rice, Shing-li-hsiang, suffers drought in the blossom phase, the crop yield greatly decreases. However, it is less damaged by drought in the phase before earing. The dissimilar reactions to drought of these two varieties in their various phases is explained in the following way: The water content in the young ear of the Lao-lai-ch'ing rice decreases but slightly during the drought; its growth continues, and therefore this variety is damaged greatly by drought in the ear phase. On the other hand, in the Shing-li-hsiang rice the water content in the young ear decreases rapidly, the growth stops, and as a result the plants are less damaged. Growth in plants of this variety resumes only after flooding (Yü Shu-wing, unpublished). The critical period for the watering of rice,

according to preliminary data, is the five-leaved phase and also the phase of differentiation of the ears (Ts'ui Ti-ling, unpublished).

By hardening wheat seeds of the variety Nanda 2419 against drought prior to sowing, the absorbing power and the activity of the enzymes (catalase and amylase) are increased, the energy of germination of the seeds is intensified, and the number of hydrophilic colloids is increased (Yu Shu-wing, 1958; Tjihn K'uang-hua, 1957). Under soil drought conditions the quantity of combined water in hardened plants has a tendency to increase while the osmosis of electrolytes from the leaves is less than in the control. Under various conditions of soil humidity the increase in the crop due to hardening the plants fluctuates from 5 to 3%. The resistance of plants to drought also increases when the seeds are treated with trace elements. When cotton seeds are treated with a copper sulfate solution, the sprouts from these seeds have highly developed root systems, the transpiration of the cotyledons is intensified, and the size of the stomata and the absorbing power are increased (Kuei Myi-hsiang, 1957).

The salt resistance of tens of species of wood plants in the sprouting phase during transplanting and grafting was determined in experiments in which salts was added to the soil of the vegetation vessels. It was evident, as a result of these experiments, that shoots of Ailanthus Altissima, Swingle, and Aepoium seliterum Roxb. ar the most resistant to salt, followed by shoots of Robinia pseudoacacia L., Sephora japonica L., Thuja orientalis L., Amorpha fruticosa L. and Gleditschia sinensis, which are less resistant.

It appeared in experiments on transplanting cuttings that Robinia pseudoacacia is the most salt-resistant plant and that Amorpha fruticosa, Sophora japonica L., Ultima sp. and Gleditschia sinensis are in the second place.

The root cuttings of ulmus and tamarisk are quite salt-resistant. When the quantity of salts in the soil increases, the germination of the seeds decreases, the appearance of sprouts is delayed, the percentage of the shoots destroyed increases, the plants decrease in height and, finally, the development of the root system is weakened. When the addition of salts is gradual, the damage is less than when a single addition is made; this shows the capacity of the cuttings to adjust to the salt (Ting Ching and others, 1956). The results of experiments with 35 species of wood plants made on salty soils in Ta-fung county of Hsiang-su province (The Experimental Station of the Coastal Forest Protection Commission, 1958) were similar to the above data. The salt resistance of various agricultural plants, in addition to that of varieties of trees, was determined by Huang P'yi-shuhng (1957).

When the method of P. A. Henkel was used in the treatment of Sophora japonica seeds with an Nacl-Cacl solution prior to planting, the following data were obtained: the number of live cells and the quantity of hydrophilic colloids in the leaves was greater in the experimental seeds than in the control, i.e., the resistance to salt was increased (Fang I-sung, unpublished).

The resistance to salt is not the same in all phases of growth and development of the plants. Rice in the tiller phase is sensitive to salting, the sensitivity being greater in the last vegetation period. Salting in the tube phase leads to the formation of abnormal spikes and decreases the tiller productivity and the crops (Ting Ching, Fang I-sung, 1957). In cotton (Commission on the Utilization of Salted Soils of Hsiang-su Province, 1956) and feeding grasses also (Yu T'ieng-Tjihn and others, 1956) the sensitivity to salt is higher in the first vegetation phases.

Comparing the salt resistance of leaf blades, sepals and sprouts of the mangrove mother plant, P. A. Henkel and Fang I-sung discovered that the salt resistance of the sprouts was larger than that of the flowers and fruits. They arrived at the conclusion that during germination the sprouts on the mother plant had adjusted to being salted.

Winter wheat of the Sao-Yang-mai variety is quite cold-resistant and does not perish in 36 hours at a temperature of -15°. The ratio of combined water to free water in this variety is very great, the respiration is weak, and the permeability of the cell is stable (Kao Yü-ch'u and others, 1957). In the subtropical region of our country the absorbing power of the rubber plant (Hevea brasiliensis) decreases as the temperature falls, but relative decrease in transpiration intensity is not as great, which results in a distrubance in the water balance that damages the tree (Hsiehng Iyu-mohsü, Shen Lu-wusung, 1957).

Dense sowing was an important factor in the rich harvest obtained in the agricultural production in 1958. The maximum density of plants in a rich harvest of rice was 800,000 per mu (1/15 ha). The optimum norm for wheat sowing was 215-375 kg/ha. However, too dense a planting weakens the illumination, so that the vegetative mass of the plants develops and the plants easily become topheavy and lie down.

A method of combining the soil moistening, irrigating with a small water layer and drying the soil was developed for irrigating rice. The use of this method made it possible to obtain excellent crops in the basin of the Yangze River. The advantages of this method are as follows: the air humidity among the plants decreases, the oxidation-reduction potential of the soil is improved, the development of the root system

is intensified, the upper part of the plants are well developed, and the overgrowth of the vegetative mass, which eventually causes plants to topple over, is inhibited. Another factor in obtaining high yields is the use of large doses of organic fertilizers. A special feature of organic fertilizers is that the plants are not damaged when large doses are given; N, P and K are more uniformly distributed, which improves the physicochemical and biological condition of the soil; and the organic fertilizers break up slowly and continuously supply the plants with mineral food. Deep plowing is also an effective method for obtaining high yields. The most favorable plowing depths are around 26 cm, too deep a plowing being unfavorable.

To determine the optimum area of feeding on each plot it is necessary to study the relation of each individual plant to the total plant population, /and the ratio/ of the portion above ground to the underground portion. The principal factor affecting the yield of cotton is the defoliation of the pods, in the soybean yield the falling off of the beans, and in the rape yield the falling off of the legumes and their sterility. All these losses result from disturbances in the normal relationship between the vegetative and generative growths. It is necessary to regulate the equilibrium of this relationship to obtain high yields of these cultivated plants.

Conclusion

The development of plant physiology in China for the last 10 years may be outlined from the foregoing. Scientific research studies were related basically to the needs for economic reconstruction in our country. Ten years is not a long period; however, during this time we set up laboratories, trained cadres of workers, and created necessary conditions for scientific studies and in addition we carried on research studies over quite a wide front. Consequently, many of the studies describe the phenomena only superficially, and thus do not reveal their true nature. A most important defect in our work is that we were not able to make much use of the knowledge and methods of modern biochemistry and biophysics.

As to our work in plant physiology in the future, we must proceed in the selection of subjects from the urgent tasks and needs of the economic reconstruction of the country and from the practical problems of agriculture. Of the large number of problems before the plant physiologists we must ferret out the most important, decisive ones and carry on deep, systematic investigations, raising practical experience to the level of theory and, conversely, on the basis of theory

finding solutions to practical problems.

It is necessary, therefore, to give attention to the study of basic theoretical problems. For this purpose we must use new, progressive methods in making scientific studies. We are confident that under the leadership of the Communist Party and with the support of all the people of our land, Chinese plant physiology will develop in the next 10 years even more rapidly and fully.

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